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# WORTHINGTON MOUNTAINS G-E-M

# RESOURCES AREA

# (GRA NO. NV-18)

# TECHNICAL REPORT

# (WSA NV 040-242)

Contract YA-554-RFP2-1054

Prepared By

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Final Report

May 6, 1983

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# EXECUTIVE SUMMARY

The Worthington Mountains Geology-Energy-Minerals (GEM) Resource Area (GRA) includes the following Wilderness Study Area (WSA): NV 040-242. The Worthington Mountains GRA is located in northwestern Lincoln County, Nevada, approximately twenty miles north of the old mining camp of Tempiute.

The GRA and the included WSA are dominated geomorphically by the Worthington Mountains which are composed primarily of Paleozoic, 225 to 570 million years old, carbonate rocks. Younger volcanic rocks are found in the lower-lying foothills in the southeastern part of the WSA, and two granitic intrusive plugs are found near the northern end of the Worthington Range in the vicinity of the Freiberg mining district and are probably largely responsible for the mineral deposits in the district.

The Freiberg district, the only mining district in the GRA, had only a small production recorded prior to 1948 of $18,000 worth of silver, gold, lead and zinc from veins and lenses in limestone. Tungsten in the form of scheelite is found in the western part of the district in close proximity to intrusives. There is current interest in possible disseminated precious metals in this environment. Both patented and unpatented claims are found in the district and no claims are found outside the district. The only claims in the WSA are a few along its northern boundary, adjacent to the Freiberg district.

The area of the WSA adjacent to the Freiberg mining district in the north is considered to have a moderate favorability for metallic minerals with a moderate confidence in the bedrock areas and a low confidence level in the alluvium. The remainder of the Worthington Mountains has a low favorability for metallics with a low confidence level in the bedrock areas and a very low confidence level in the alluvium. For nonmetallics the bedrock areas of the WSA are considered to have a moderate favorability with a moderate confidence level for commodities such as silica (quartzite) and cement or lime manufacture (carbonates). The alluvium has a moderate favorability with a moderate confidence level for sand and gravel resources. Uranium has a low favorability with a low confidence level, and thorium has very low favorability with very low confidence throughout the WSA. Oil and gas has a low favorability with a very low confidence level. Geothermal has a low favorability on the flanks of the range and a very low favorability in the range with a very low confidence level.

Recommendations include more detailed mapping of both the Freiberg district and the rest of the Worthington Range.

# I. INTRODUCTION

The Worthington Mountains G-E-M Resources Area (GRA No. NV-18) contains approximately 150,000 acres (590 sq km) and includes the following Wilderness Study Area (WSA):

| WSA Name | WSA Number |
|---|---|
| Worthington Mountains | NV 040-242 |

The GRA is located in Nevada within the Bureau of Land Management's (BLM) Schell and Caliente Resource Areas of the Ely and Las Vegas districts. Figure 1 is an index map showing the location of the GRA. The area encompassed is near 37°50' north latitude, 115°33' west longitude and includes the following townships:

T 1 N, R 56, 57 E
T 1 S, R 56, 57 E
T 2 S, R 56, 57 E

There are no 15-minute or 7.5-minute topographic maps for this GRA.

The nearest settlement is Tempiute which is located about six miles south of the southern GRA boundary. Access to the area is via State Highway 25 to the southwest and the Sand Spring Valley Road. Access within the area is via dirt roads and trails scattered throughout the GRA, with some extending into the west side of the WSA.

Figure 2 outlines the boundaries of the GRA and the WSA on a topographic base at a scale of 1:250,000.

Figure 3 is a geologic map of the GRA and vicinity, also at 1:250,000. At the end of the report, following the Land Classification Maps, is a geologic time scale showing the various geologic eras, periods and epochs by name as they are used in the text, with the corresponding age in years. This is so that the reader who is not familiar with geologic time subdivisions will have a comprehensive reference for the geochronology of events.

This GRA Report is one of fifty-five reports on the Geology-Energy-Minerals potential of Wilderness Study Areas in the Basin and Range province, prepared for the Bureau of Land Management by the Great Basin GEM Joint Venture.

The principals of the Venture are Arthur Baker III, G. Martin Booth III, and Dennis P. Bryan. The study is principally a literature search supplemented by information provided by claim owners, other individuals with knowledge of some areas, and both

specific and general experience of the authors. Brief field verification work was conducted on approximately 25 percent of the WSAs covered by the study.

The WSA in this GRA was not field checked.

One original copy of background data specifically applicable to this GEM Resource Area Report has been provided to the BLM as the GRA File. In the GRA File are items such as letters from or notes on telephone conversations with claim owners in the GRA or the WSA, plots of areas of Land Classification for Mineral Resources on maps at larger scale than those that accompany this report if such were made, original compilations of mining claim distribution, any copies of journal articles or other documents that were acquired during the research, and other notes as are deemed applicable by the authors.

As a part of the contract that resulted in this report, a background document was also written: Geological Environments of Energy and Mineral Resources. A copy of this document is included in the GRA File to this GRA report. There are some geological environments that are known to be favorable for certain kinds of mineral deposits, while other environments are known to be much less favorable. In many instances conclusions as to the favorability of areas for the accumulation of mineral resources, drawn in these GRA Reports, have been influenced by the geology of the areas, regardless of whether occurrences of valuable minerals are known to be present. This document is provided to give the reader some understanding of at least the most important aspects of geological environments that were in the minds of the authors when they wrote these reports.

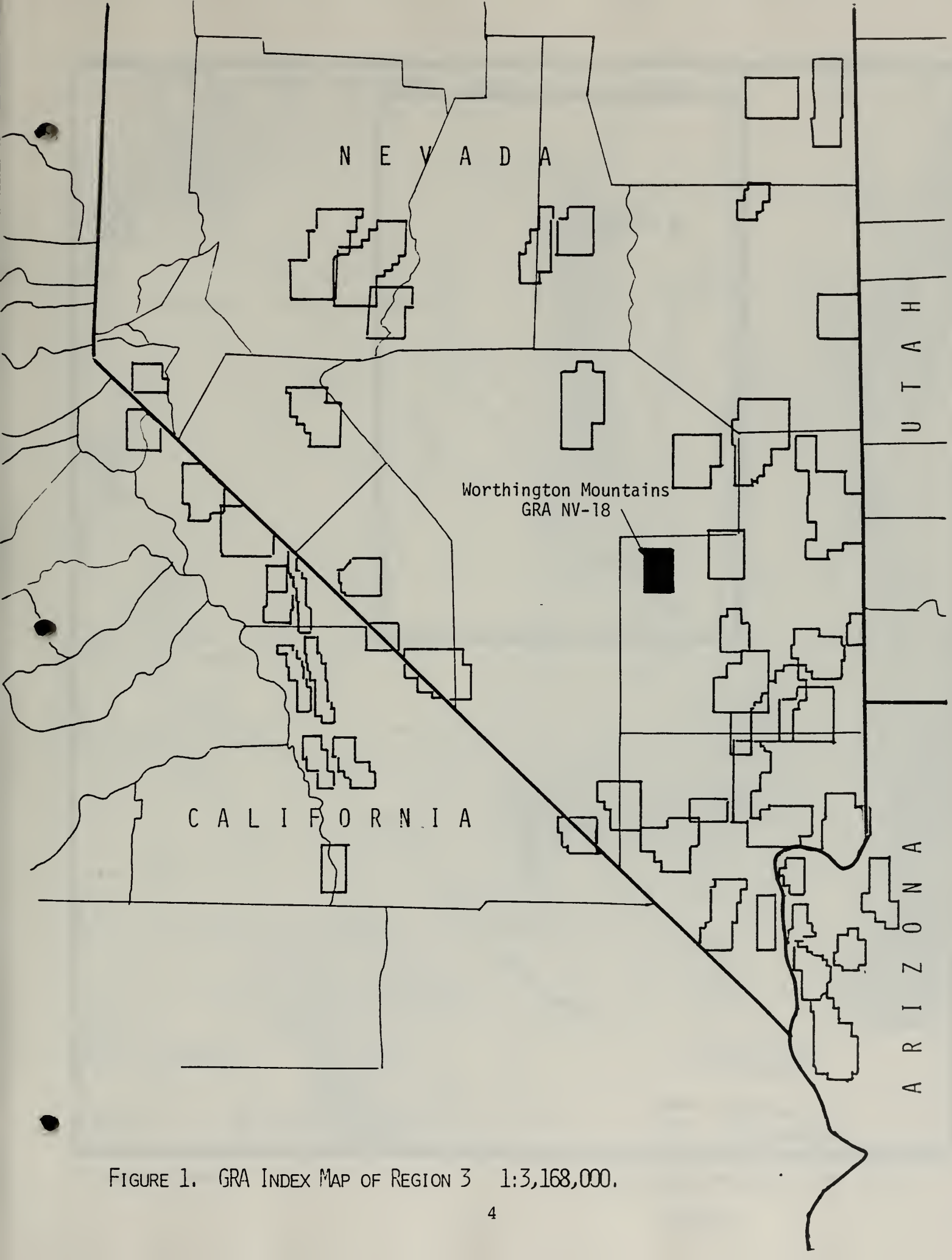
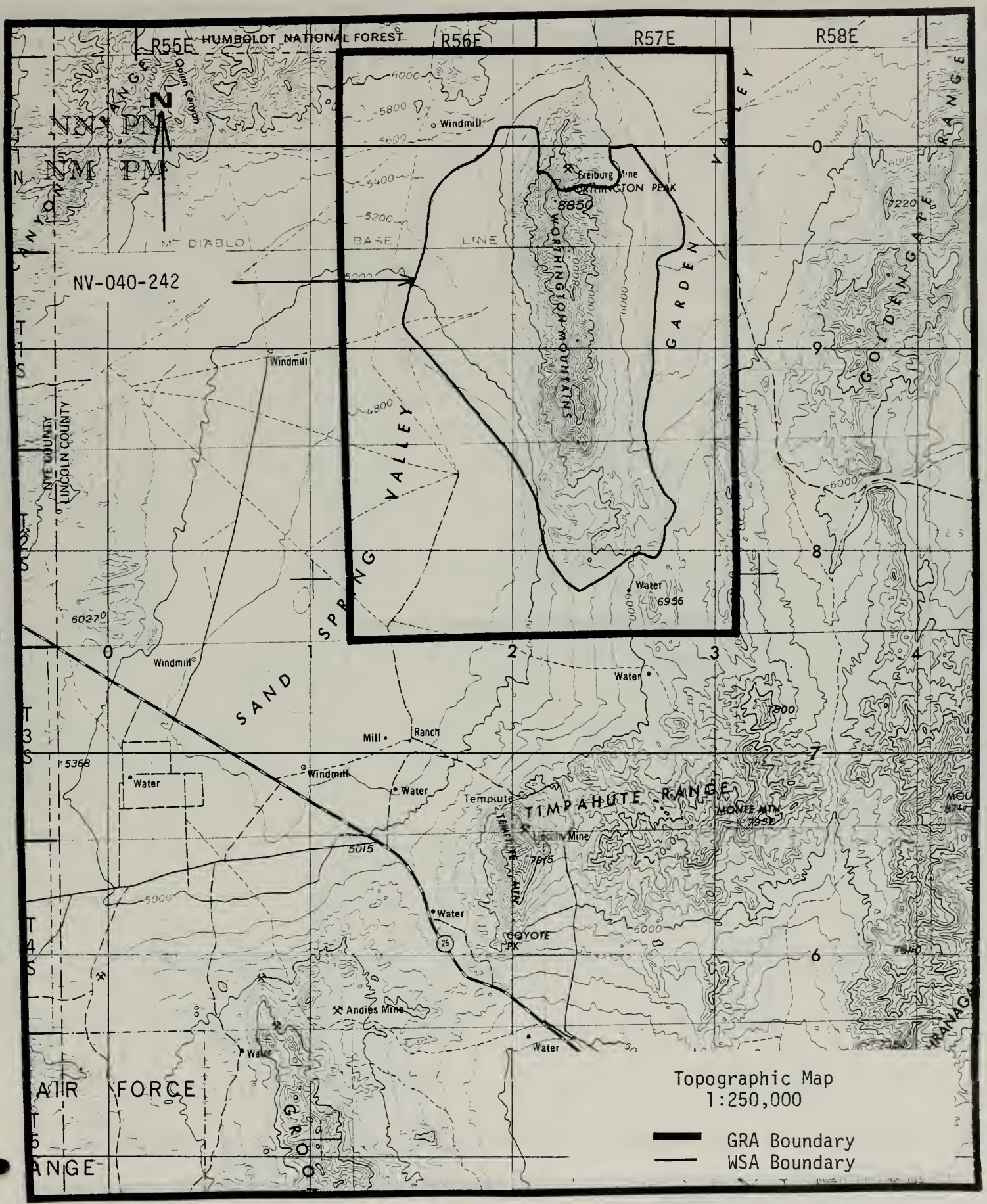


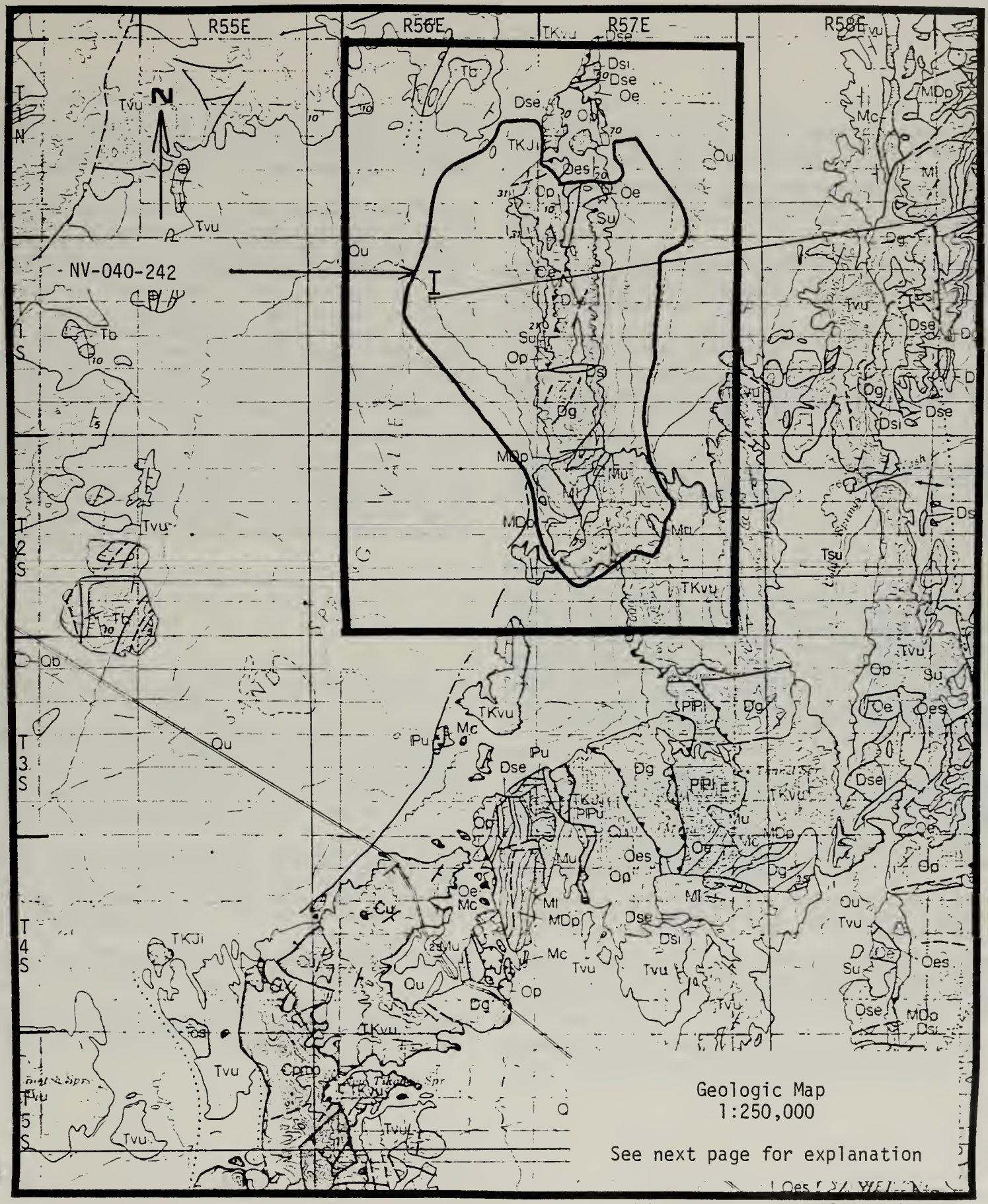

FIGURE 1. GRA INDEX MAP OF REGION 3 1:3,168,000.




Caliente Sheet

Worthington Mountains GRA NV-18

Figure 2




Howard (1978)

Worthington Mountains GRA NV-18

Figure 3

# EXPLANATION

## Cenozoic Sediments

Quaternary, Undifferentiated (Qu): *Includes all sedimentary rocks and surface exposures of recent playa deposits, dune sands, lake beds, shoreline deposits and younger as well as certain older exposures of gravels and other alluvium associated with pediments and mountain streams.*

Tertiary Younger Sediments (Tys): *Sedimenetary rocks of Miocene and Pliocene age including older lake beds of the Muddy Creek Formation and Panaca Formation in Lincoln and Clark Counties; the Muddy Creek Formation in Southwestern Utah; pre-Quaternary sediments in the White River Valley; and sediments associated with ash-flow tuffs near Antelope Summit in White Pine County.*

Tertiary Sediments, Undifferentiated (Tsu): *Primarily Miocene and upper Oligocene deposits including tuffaceous sediments interbedded with ash flow tuffs, the Horse Camp Formation and various unidentified tuffs, tuffaceous shales and diatomites in Nye County; intravolcanic tuffaceous and clastic sedimentary rocks in Lincoln and Nye Counties; and conglomerates and limestones of uncertain age in the Conger-Confusion Ranges and the Cricket Mountains of Utah.*

Tertiary Older Sediments (Tos): *Includes the Sheep Pass Formation in Lincoln and Nye Counties; the Gilmore Gulch Formation in Nye County; unnamed lacustrine limestones in southern Lincoln County; older gravels, conglomerates, tuffaceous and clastic sedimentary rocks, limestones, cherts, claystones, silts, carbonaceous shales and oil shales in Elko County; and older limestones of the Illipah area and the Kinsey Canyon Formation of the Schell Creek and Grant Ranges in White Pine County.*

## Cenozoic Volcanics

Quaternary Basalt (Qb): *Basalt, andesite and latite of Quaternary or late Tertiary age in Nye County.*

Tertiary Basalt (Tb): *Intermediate and basaltic lavas including the Fortification Basalt Member of the Muddy Creek Formation in Clark County; basalt flows, basaltic cinder, tuff and lava cones which are included in parts of the Banbury Formation and latite flows in Elko County; basalt flows and dikes in Lincoln County; andesite and basalt flows of various ages in North Central Nevada; and basalt and basaltic andesite flows in Southwestern Utah.*

Tertiary Volcanics, Undifferentiated (Tvu): *Early to late Tertiary volcanic rocks ranging in composition from silicic to intermediate; primarily rhyolites, dacites, quartz latite flows, ignimbrites and pyroclastics of widespread occurrence. These rocks are listed under various subdivisions in Elko, Lincoln, and Nye Counties; North Central Nevada and Southwestern Utah.*

Tertiary Older Volcanics (Tov): *Pre-Miocene volcanic rocks lithologically similar to Tertiary Volcanics, Undifferentiated (Tvu). Listed under various subdivisions in Nye County.*

Intrusives (TKJi): *Occurred from mid-Jurassic through late Tertiary. Widespread intrusions ranging in composition from granitic through gabbroic and in texture from holocrystalline to porphyritic.*

## Mesozoic Sediments

Tertiary-Cretaceous Sediments (TKsu): *Continental sediments consisting of fanglomerates, clastics, tuffs and limestones. Includes the Gale Hills Formation and the Overton Fanglomerate.*

Cretaceous Sediments (Ks): *Chiefly non-marine siltstone, shale, conglomerate and limestone. Includes lower Gale Hills Formation, Thumb Formation, Baseline Sandstone, Willow Tank and Newark Canyon Formations.*

Jurassic (Ju): *Eolian cross-bedded sandstone in Utah, volcanically derived sediments, ash flows and basic lava flows in northern Elko County. Includes Navajo Sandstone, Aztec Sandstone, Frenchie Creek Formation and Bayer Ranch Formation.*

Jurassic-Triassic (JTu): *Includes Nugget and Aztec Sandstones and Chinle Formation of southern Nevada.*

Triassic (Tu): *Shallow marine sedimentary rocks including Chinle, Shinarump, Thaynes and Moenkopi Formations in the west and continental to shallow marine sediments in the east.*

## Mesozoic Volcanics

Tertiary-Cretaceous Volcanics (TKvu): *Occur in Lincoln County where it covers wide areas of the Clover, Del Mar, Wilson Creek, White Rock and Mahogany Mountains.*

## Paleozoic Sediments

Permian, Undifferentiated (Pu): *Shallow marine intertidal and continental sediments. Includes Gerster Formation, Plympton Formation, Kaibab Limestone, Pequop Formation, Coconino Sandstone, Arcturus Formation, Rieptown Formation, Rib Hill Sandstone, Riepe Springs Formation, Carbon Ridge Formation and Loray Limestone. With the exception of parts of White Pine County, local symbols are used to identify all Permian outcrops. In White Pine County, local symbols are used except for the Park City Group which is grouped with the Arcturus and Rib Hill Sandstones (Par). To avoid confusion, non-standard symbol used for Permian in Utah has been replaced with the standard "P".*

Pennsylvanian-Permian (PPu): *Marine sandstone and limestone (dolomatized in places). Includes Rib Hill Sandstone, Riepe Spring Limestone and Ferguson Mountain Formation in southern Elko County; Strathearn Formation, Buckskin Mountain Formation, Beacon Flat Formation and Carlin Canyon Formation in Eureka County; Pablo Formation in Nye County; and Oquirrh Formation or group in Utah. Local symbols are used where possible.*

Pennsylvanian, Undifferentiated (Pu): *Includes Ely Limestone, Moleen and Tomera Formations. To avoid confusion, the non-standard symbol used for Pennsylvanian in Utah has been replaced by "P".*

Mississippian Upper (Mu): *Includes Diamond Peak and Bird Spring Formations, Callville Limestone, Scotty Wash Formation, Ochre Mountain Limestone and Manning Canyon Shale in parts of Clark County. Chainman Shale is combined with Diamond Peak Formation in some parts of Utah.*

Mississippian, Chainman Shale (Mc): *Includes Mountain City Formation in Elko County and Elcana Formation in Nye County.*

Mississippian, Lower ( Ml ): *Includes Monte Cristo and Rogers Spring Limestones in Clark County; Joana, Mercury and Bristol Pass Limestones in Lincoln County; and Joana Limestone elsewhere.*

Mississippian-Devonian, Undfiferentiated (MDu): *Includes Rogers Spring Limestone and Muddy Peak Limestone in parts of Clark County: Joana Limestone and Pilot Shale in Elko County; Pilot Shale, Joana Limestone, Chainman Shale and Diamond Peak Formation in Eureka and White Pine Counties.*

Mississippian-Devonian, Pilot Shale (MDp): *Shown in combination with other Mississippian Formations in Clark, Elko, parts of Lincoln, Eureka and White Pine Counties.*

Devonian-Cambrian, Undifferentiated (DSO-Cu): *Undivided limestone and dolomite occurring in Lincoln County.*

Devonian-Ordovician, Undifferentiated (DSOu): *Dolomites in Elko and Nye Counties.*

Devonian, Upper (Du): *Primarily Devils Gate and Guilmette Formations. Also includes Sevy and Simonson dolomites in parts of White Pine County. Contains Guilmette, Devils Gate, Simonson and Sevy in Elko County under the heading of* Dgd. *Local symbols used where possible.*

Simonson Dolomite (Dsi): *Alternating light to dark gray fine to coarse grained dolomite. Included with other Silurian and Devonian sediments in North Central Nevada and parts of Utah. Grouped with Sevy Dolomite in parts of Clark, Elko, Eureka, Nye, and White Pine Counties.*

Sevy Dolomite (Dse): *Very light colored, dense, distinctly bedded unfossiliferous dolomite. Combined with other Devonian and Silurian sediments in parts of North Central Nevada and Utah and with the Simonson Dolomite in parts of Clark, Elko, Eureka, Nye and White Pine Counties.*

Sevy and Simonson Dolomites, combined (Dun): *Also includes the Sultan and Muddy Peak Limestones in Clark County; Nevada Formation in Elko County; Devils Gate Formation in Eureka County; Nevada Formation, Woodpecker Limestone, Oxyolk Canyon Sandstone and Rabbit Hill Formation in Nye County; Nevada Formation and Devils Gate Formation in Eureka County and the Nevada Formation in White Pine County. Local symbols are used where possible.*

Devonian, Western Facies (Dw): *A portion of the western allochthonous assemblage. Includes Woodruff Formation and Slavern Chert in Eureka County and silicious siltstone in the Cockalorum Wash area of Nye County.*

Silurian, Undifferentiated (Su): *Includes Lone Mountain and Laketown Dolomites throughout the mapping area, the Elder Sandstone and Fourmile Canyon formation in Eureka County, and the Roberts Mountain formation in Nye County. In White Pine County, the Silurian deposits are grouped with the upper Ordovician sediments under the heading of Silurian-Ordovician, Undifferentiated (SOu).*

Upper Ordovician, Undifferentiated ( Oupu ): *Includes Ely Springs and Fish Haven Dolomites and the Hanson Creek Formation. Local symbols are used where possible. Listed as Ordovician, Undifferentiated (Ou) in parts of North Central Nevada. In Clark County, Ely Springs Dolomite has been divided from the rest of* Oep *by the author. The Eureka Quartzite and Pogonip Group are grouped with Silurian sediments under the heading Silurian-Ordovician, Undifferentiated (SOu) in Elko County.*

Ordovician, Eureka Quartzite ( Oe ): *Light colored vitreous quartzite and hard sandstone. Also includes the Swan Peak Quartzite in parts of Utah. In Clark County, the Eureka Quartzite has been separated from* Oep *by the author. In parts of North Central Nevada, the Eureka Quartzite has been grouped with other Ordovician sediments under the heading of* Ou. *In White Pine County, the Eureka Quartzite has been grouped with the Pogonip Group under the heading of*

Ordovician, Pogonip Group (Op): *Limestone, silty limestone, shale and interformational conglomerates. In Clark County, the Pogonip Group has been separated from* Oep *by the author. Includes the Garden City Limestone in parts of Utah. In White Pine County, the Pogonip Group is grouped the Eureka Quartzite under the heading of* Ol.

Ordovician, Undifferentiated (Ou): *Includes the Pogonip Group, Ely Springs Dolomite, Eureka Quartzite and Comus Formation in North Central Nevada.*

Ordovician, Vinini Formation ( Ovi ): *Part of the western allochthonous assemblage. Includes Valmi Formation in parts of North Central Nevada. Local symbols are used where possible.*

Cambrian-Ordovician, Undifferentiated (O-Cu): *Occurs in Elko, Eureka, Nye and White Pine Counties as shale and limestone and is usually so identified when metamorphosed to phyllite. Includes the Tennessee Mountain Formation in Elko County, Board Canyon, Sequence in North Central Nevada, Windfall Formation in Nye County and the lower Ordovician and post-Dunderberg Shale in the Schell Creek Range of White Pine County. In some parts of Nye County,* O-Cu *is metamorphosed to slate and marble instead of phyllite.*

Cambrian, Upper and Middle ( -Cu ): *Primarily limestones, dolomites, shales and quartzites. Includes Edgemont and Peak Limestones in Elko County; Highland Peak formation, Patterson Pass Shale, Pole Canyon Limestone, Chisholm Shale and Lyndon Limestone member of the Chisholm Shale in Lincoln County; Harmony Formation, Preble Formation, Pioche Shale, Eldorado Dolomitee, Geddes Limestone, Secret Canyon, Hamberg, Dole and Dunderberg Shales, Windfall Formation, and Scott Canyon Formation in North Central Nevada; Windfall Formation, Dunderberg Shale, Tybo Shale and Lincoln Park Formation in Nye County; Notch Peak Formation, Dunderberg Shale, Orr Formation, Weeks Formation, Marjum Formation, Wheeler Shale, Swasey Formation, Whirlwind Formation, Dome Limestone, Howell Formation and Tatow Formation in Utah; and Corset Spring Shale, Notch Peak Limestone, Dunderberg Shale and Windfall Limestone in White Pine County. Metamorphosed to schist in Elko County.*

Cambrian, Lower (-Cpmp): *Primarily Prospect Mountain Dolomite and Pioche Shale. Also includes Tapeats Sandstone, Wood Canyon Formation, Lyndon Limestone, Chisholm Shale and Carrera Formation in Clark County; Sterling Quartzite and Wood Canyon Formation in parts of Lincoln County; Busby Quartzite in the Gold Hill area of Utah and the Stella Lake Quartzite in White Pine County.*

Precambrian

Precambrian Sediments (p-Cs ): *Includes the Johnnie Formation, Sterling Quartzite and some metamorphics in Clark County; Johnnie Formation and lower units of Prospect Mountain Quartzite in Lincoln County; McCoy Creek Group in Elko County; and the McCoy Creek Group excluding the Stella Lake Quartzite in White Pine County.*

Precambrian Intrusives ( p-Ci ): *Includes the Gold Butte Granite in Clark County and other undifferentiated igneous and metamorphic rocks, primarily granites and pegmatites.*

# II. GEOLOGY

The Worthington Mountains GRA lies within the Basin and Range province in northwestern Lincoln County, Nevada (see Figure 2). WSA 040-242 includes most of the Worthington Mountains, a north-south-trending narrow range of faulted Paleozoic sediments (see Figure 3) which have been locally intruded by Tertiary granitic stocks in the north.

The Worthington Mountains are bound by north-south-trending range front faults as evidenced by the steep linear escarpments. The Frieburg thrust in the central portion of the range has placed older members of the Pogonip Group over younger members of the same formations. On the northern tip of the range complexly faulted sediments appear to be a remnant of a second thrust sheet.

Numerous normal faults in the bedrock units transect the Paleozoic sediments mostly in the southern end of the range and terminate at the range front faults.

The Freiburg mining district, in the northern portion of the GRA, contains small precious and base metal bearing irregular replacement lenses along faults in limestone and scheelite deposits in tactite. Both mineralization types are genetically related to the intrusive granitic rocks in the northern part of the range.

Most of the following geological description is taken from Tschanz and Pampeyan, 1970.

## 1. PHYSIOGRAPHY

The Worthington Mountains GRA lies within the Basin and Range province in northwestern Lincoln County, Nevada. WSA 040-242 includes most of the Worthington Mountains, a north-south-trending narrow range of faulted Paleozoic sediments which have locally been intruded in the north by Tertiary granitic stocks. Adjacent portions of Sandy Spring and Garden Valleys are also included. The existing workings of the Freiburg district at the northern end of the range is not within the WSA boundary but has been included in the GRA.

The topography of the Worthington Mountains is rugged with elevations along the crest of the range averaging about 7,500 feet while Sand Spring Valley to the west is near 4,800 feet. Range front faults bound the Worthington Mountains, forming steep escarpments.

Drainage of the range is to adjacent valleys with the west flank of the range discharging into Sand Spring Valley and the east flank of the range draining into Garden Valley.

## 2. ROCK UNITS

Formations ranging from the Ordovician Pogonip Group to an unnamed Mississippian limestone unit are exposed in the Worthington Mountains, with the younger rocks occurring at the southern end.

The oldest strata, the Pogonip Group, is the host for mineralization in the Freiburg district and consists of alternating, thick-bedded, cliff-forming limestone and thin-bedded, slope-forming silty and shaly limestone. This sequence is overlain by the Eureka Quartzite, a prominent typically light colored massive or crossbedded orthoquartzite. The Ely Springs Dolomite, a dark gray to black fossiliferous unit, was next deposited during the upper Ordovician.

The Silurian Laketown Dolomite, composed of alternating light and dark gray crystalline dolomite sequences, generally forms a bold three-part outcrop (Tschanz and Pampeyan, 1970).

The Sevy Dolomite, a conspicuous, remarkably homogenous microcrystalline dolomite that weathers to a characteristic whitish gray, was unconformably deposited over the Laketown Dolomite in lower Devonian time. The Simonson Dolomite, composed of alternating sequences of light and dark dolomite of several types, was next deposited. The Middle-Upper Devonian Guilmette Formation, consisting of a sandy limestone facies, a dolomite facies, and a limestone facies, was the next deposited formation.

Unconformably overlying the Guilmette, is the Upper Devonian-Lower Mississippian Pilot Shale. In this area the Pilot Shale contains comparatively little shale and is composed mainly of thin-bedded silty limestone and calcareous platy siltstone.

An unnamed Mississippian limestone unit that consists of all the limestone is between the Pilot and Chainman Shales. This unit includes the Joanna Limestone and an unnamed overlying unit of thin- to thick-bedded slope-forming limestone.

An upper Mississippian undivided sequence of clastic rocks has locally been divided into the Chainman Shale, and the Scotty Wash Quartzite.

Undivided Cretaceous-Tertiary volcanic sequences crop out in the southern part of the range and in a small area northwest corner of the GRA. This unit includes a thick conglomerate unit.

Oligocene-Early Pliocene undivided younger volcanics occur in the northwest corner of the GRA. These rocks are predominantly an ignimbrite series that consists of welded and crystal tuffs, pumice, tuff breccias, flows and perlitic units that range in composition from basalt to rhyolite. An Early Pliocene basalt unit locally caps the Tertiary volcanics in

this area.

Mid-Tertiary granitic stocks and related small irregular masses of granitic rocks and mafic dikes have been intruded in the Freiburg area. Metallic mineralization in the Freiburg district occurred subsequent to the emplacement of these intrusive stocks as late stage fluids from the cooling magmas sought structurally favorable conduits adjacent favorable host rocks or depositional environments. Sedimentary rocks surrounding these intrusives are recrystallized, dolomitized, or converted to tactite.

Plio-Pleistocene(?) older gravels and intermediate lake beds unconformably overlie the older formations and are exposed on the flanks of the range in Garden and Sand Spring Valleys.

## 3. STRUCTURAL GEOLOGY AND TECTONICS

The principle structure in the Worthington Mountains is the Freiberg thrust, a west-dipping thrust plate of west-dipping Ordovician rocks and Devonian rocks on the west side of the range. On the north end of the plate, thrusting is within the Pogonip limestone. The stratigraphic separation along the thrust increases southward. At the northern tip of the range complexly faulted Paleozoic sediments appear to be a remnant of a second thrust sheet (Tschanz and Pampeyan, 1970).

High linear range fronts suggest that Basin and Range frontal faults exist along both sides of the Worthington Mountains. The northwest-trending Penoyer fault, which terminates at the southern end of the Worthington Mountains, extends for about 15 miles along the southeastern border of Sand Spring Valley.

Several east-west-trending normal faults cut the Paleozoic sediments and terminate at the range front faults indicating that they are younger than Miocene-Pliocene Basin and Range faulting. In the southern half of the range there are numerous normal faults, many of which were not included on the map of Lincoln County (Tschanz and Pampeyan, 1970). These faults trend both northeast and northwest.

## 4. PALEONTOLOGY

The major rocks of this GRA with potential for paleontological resources are the Pogonip Group, Laketown, Elena Formation (?), Sevey and Simonson Dolomites and equivalents of the Nevada Formation. No precise localities are known from this GRA, although fossils occur in the Silurian and Ordovician rocks discontinuously along strike.

Other lithologies within this GRA are minor.

## 5. HISTORICAL GEOLOGY

Throughout the Paleozoic miogeosynclinal rocks were deposited throughout the area. Sediments deposited during the Mesozoic were largely eroded over most of Lincoln County during the orogenic period that began with uplift in Late Triassic time and culminated in thrust faulting during the Cretaceous.

This orogeny was followed by a period of mid-Tertiary volcanism. Thick sequences of volcanics, predominently ignimbrites, were deposited at this time.

Subsequent to the volcanism, Basin and Range faulting during Miocene-Pliocene time formed much of the present-day topography. Lake beds were deposited during Pliocene(?)-Pleistocene(?) time in structural basins along with thick sequences of clastic material derived from nearby mountains.

## III. ENERGY AND MINERAL RESOURCES

### A. METALLIC MINERAL DEPOSITS

#### 1. Known Mineral Deposits

The GRA contains one mining district, the Freiburg district, at the north end of the Worthington Range (see Metallics Land Classification and Mineral Occurrence Map). Total production from the district amounted to only approximately $18,000 between 1919 and 1948. Production from the district included gold, silver, lead and zinc. Most of the production has come from irregular and small replacement veins or lenses along faults in limestones of the Pogonip Group near the easternmost intrusive stock, which has either marblized or partly silicified the limestones. Most of the ore is oxidized with galena and pyrite the only sulfides. Both gold and silver-lead veins are present and some of the deposits have a well-developed gossan. It is reported that one fifty ton shipment contained 70.6 ounces of silver and 6.5 percent lead (Tschanz and Pampeyan, 1970).

#### 2. Known Prospects, Mineral Occurrences and Mineralized Areas

Tungsten in the form of scheelite is found in the tactites at the limestone-intrusive contact of the western intrusive stock, but there has been no reported scheelite production. Scheelite is disseminated in a light green tactite which contains what is believed to be wolframite. The tactite probably contains less than 0.4 percent $WO_3$ (Tschanz and Pampeyan 1970). The tactite has been explored by a shallow shaft in Sec. 7, T 1 N, R 57 E, but much of the area of tactite has reportedly not been explored as of 1970 and Tschanz and Pampeyan (1970) indicate a considerable area of tactite favorable for scheelite deposits still remain to be explored.

No other metallic mineral resources have been reported in the literature in the GRA. The Nevada Mining Association (1983) indicates however, that there is a silver tungsten prospect several miles outside the Freiburg district but its location is not given. Field work during a mineral inventory of this area by Terradata (1980) in 1979 indicated there were 20 to 30 recent rotary drill holes near the eastern edge of Sec. 17, T 1 N, R 57 E.

#### 3. Mining Claims

There are approximately 160 lode claims staked in the Freiberg district in parts of at least 12 sections, and some of the claims overlap into the northern part of the WSA. Most of the claims are part of the Willow Creek

Group, and according to the BLM's records the claimants include, among others: Brigham Young University, the Boy Scouts of America and Einar C. Erickson.

There are no other known claims in the WSA outside those found in conjunction with the Freiburg mining district mentioned above.

4. Mineral Deposit Types

The gold, silver, lead and zinc are found in replacement or vein deposits in limestones near the eastern intrusive stock. The lead-silver indicates a relatively high temperature type deposit. The carbonate rocks that are abundant in the stratigraphic column here could be good hosts for low temperature disseminated gold deposits.

The scheelite is found in tactite which is the contact deposit between igneous intrusives and limestones.

5. Mineral Economics

Small irregular replacement deposits along veins are generally uneconomical to mine underground. Likewise, small, low-grade scheelite deposits are not attractive targets at this time. If grade could be improved, more continuous mineralization found, or larger low-grade deposits found which could be open-pit mined, the district could possibly show renewed activity.

The major use of gold is for storing wealth. It is no longer used for coinage because of monetary problems, but many gold "coins" are struck each year for sale simply as known quantities of gold that the buyer can keep or dispose of relatively easily. The greatest other use of gold is in jewelry, another form of stored wealth. In recent years industrial applications have become increasingly important, especially as a conductor in electronic instrumentation. In the United States and some other countries gold is measured in troy ounces that weigh 31.1 grams -- twelve of which make one troy pound. Annual world production is about 40 million ounces per year, of which the United States produces somewhat more than one million ounces, less than one-fourth of its consumption, while the Republic of South Africa is by far the largest producer at more than 20 million ounces per year. World production is expected to increase through the 1980s. For many years the price was fixed by the United States at $35 per ounce, but after deregulation the price rose to a high of more than $800 per ounce and then dropped to the neighborhood of $400 per ounce. At the end of 1982 the price was $460.50 per ounce.

The major uses of silver are in photographic film, sterlingware, and increasingly in electrical contacts and conductors. It is also widely used for storage of wealth in the form of jewelry, "coins" or bullion. Like gold it is commonly measured in troy ounces, which weigh 31.1 grams, twelve of which make one troy pound. World production is about 350 million ounces per year, of which the United States produces about one-tenth, while it uses more than one-third of world production. About two-thirds of all silver is produced as a by-product in the mining of other metals, so the supply cannot readily adjust to demand. It is a strategic metal. Demand is expected to increase in the next decades because of growing industrial use. At the end of 1982 the price of silver was $11.70 per ounce.

The largest use for lead is in electrical storage batteries, the second being a gasoline antiknock additive. It has many other uses, however, including radiation shielding, solders, numerous chemical applications and in construction. About four million metric tons of lead are produced in the world annually. The United States produces about half a million tons per year, and recovers about the same amount from scrap -- much of it through the recycling of old batteries. It imports about one-quarter of a million tons. Lead is classified as a strategic mineral. Demand is projected to increase somewhat in the next couple of decades, but environmental concerns will limit the increase. The United States has large ore reserves that are expected to last well beyond the end of this century at current production rates even without major new discoveries. At the end of 1982 the price was about 22 cents per pound.

The major uses of zinc are in galvanizing, brass and bronze products, castings, rolled zinc and in pigments or other chemicals. About six million metric tons are produced annually, with the United States producing somewhat less than a quarter of a million tons. Domestic production has decreased dramatically over the past five years, largely as the result of closing down of most zinc smelters because of environmental problems. Imports into the United States are about one million tons per year, and zinc is listed as a strategic and critical metal. Both world-wide and domestic consumption are expected to increase at a moderate rate over the next twenty years. At the end of 1982 the price of zinc was about 38 cents per pound.

More than half of all tungsten used is in the form of tungsten carbide, a hard and durable material used in cutting tools, wear-resistant surfaces and hard-faced welding rods. Lesser quantities are used in alloy steels, in light bulb filaments, and in chemicals. World production of tungsten is nearly 100 million pounds

annually, of which the United States produces somewhat more than six million pounds, while using more than 23 million pounds. The shortfall is imported from Canada, Bolivia, Thailand and Mainland China, as well as other countries. Tungsten is a strategic and critical metal. United States demand is projected to about double by the year 2000, and most of the additional supply will probably be imported, because large reserves are in countries in which profitability is not a factor -- they need foreign exchange, and therefore sell at a price that few domestic mines can match. Tungsten prices F.O.B. are quoted for "short ton units", which are the equivalent of 20 pound of contained tungsten. At the end of 1982 the price of tungsten was about $80 per short ton unit.

## B. NONMETALLIC MINERAL RESOURCES

### 1. Known Mineral Deposits

There are no reported nonmetallic mineral deposits known in the GRA.

### 2. Known Prospects, Mineral Occurrences and Mineralized Areas

There are no reported nonmetallic mineral occurrences or prospects in the GRA. The Worthington Mountains, however, contain abundant carbonate units which could be raw material for lime or cement manufacture and other units which could be utilized in various construction type uses. The Eureka Quartzite could be a source of silica.

### 3. Mining Claims, Leases and Material Sites

There are no mining claims in the GRA which are known or even suspected of being staked for nonmetallic mineral resources. There are no known material sites in the WSA, but there is considerable alluvial materials which could probably be utilized as sand and gravel.

### 4. Mineral Deposit Types

The only nonmetallic commodities present in the GRA are sedimentary rocks (limestones, dolomites, quartzites, shales) and recent alluvium.

### 5. Mineral Economics

It is unlikely that the carbonate units will be utilized for cement or lime manufacture as this area is not close to the major markets and there is an abundance of

carbonate resources closer to the potential markets. Likewise, the use of raw materials for construction would probably be limited and confined to projects in the immediate area.

Pure limestone and dolomite are used principally to produce lime, but some is used as rock for building stone, crushed rock, and similar applications. The principal uses of lime are in steel smelting, water purification, as an alkali, in paper and pulp manufacture, and sewage treatment. Other uses for lime are in sugar purification, mortar, and as an agricultural soil conditioner. Limestone with certain clay impurities (called cement rock), or purer limetsone with clay added, is used to make cement that is mostly consumed in construction. The United States uses about 20 million tons of lime and 85 million tons of cement annually. For both lime and cement the raw material must be mined within a very few miles of the processing plant, because it has a very low value in the form of run-of-mine rock -- two or three dollars per ton. There are numerous lime and cement plants in the United States, and most of them sell most of their product within a 200 mile radius of the plant. Some cement is imported in the form of clinker, which is the kiln-fired rock that is then ground in the United States. In the early 1980s the price F.O.B. plant of both lime and cement is about $40 per ton.

A large but unknown proportion of silica or industrial sand is used in making glass, which is almost entirely silica. The second largest use is as foundry sand which is used to make molds for metal castings, and some is used as a flux in certain smelting operations. Sand is used as an abrasive in applications such as sandblasting, as a filter in various kinds of water treatment, and in a multitude of minor uses. The United States uses about 30 million tons of silica sand annually, essentially all produced domestically. Except for highly specialized sands, silica sand is a relatively low-priced material and must be produced within a few hundred miles of the point of use. Silica sand consumption in the United States is forecast to increase by about 50 percent by the year 2000. The average price for silica sand is about $10 per ton, but the price for specific sands varies widely depending on the end use and the specifications required.

The most common use of sand and gravel is as "aggregate" -- as part of a mixture with cement to form concrete. The second largest use is as road base, or fill. About 97 percent of all sand and gravel used in the United States is in these applications in the construction industry. The remaining three percent is used for glassmaking, foundry sands, abrasives, filters and similar applications. The United States uses nearly one billion tons of sand and gravel annually, all of it produced

domestically except for a very small tonnage of sand that is imported for highly specialized uses. Since construction is by far the greatest user of sand and gravel, the largest production is near sites of intensive construction, usually metropolitan areas. Since sand and gravel are extremely common nearly everywhere, the price is generally very low and mines are very close to the point of consumption -- within a few miles as a rule. However, for some applications such as high-quality concrete there are quite high specifications for sand and gravel, and acceptable material must be hauled twenty miles and more. Demand for sand and gravel fluctuates with activity in the construction industry, and is relatively low during the recession of the early 1980s. Demand is expected to increase by about one third by the year 2000. In the early 1980s the price of sand and gravel F.O.B. plant averaged about $2.50 per ton but varied widely depending upon quality and to some extent upon location.

## C. ENERGY RESOURCES

### Uranium and Thorium Resources

1. Known Mineral Deposits

There are no known uranium or thorium deposits in the WSA or GRA.

2. Known Prospects, Mineral Occurrences, and Mineralized Areas

There are no known uranium or thorium occurrences in the WSA or GRA. However, there is one uranium occurrence in the area south of the GRA at the Tem Piute Mine in Sec. 36, T 3 S, R 56 E (Garside, 1973) (see Uranium Land Classification and Mineral Occurrence Map). At this location autunite occurs along a fault in diopside-garnet tactite, which formed in the contact zone of a quartz monzonite intrusion.

3. Mining Claims

There are no known uranium or thorium claims or leases in the WSA or GRA.

4. Mineral Deposit Types

Deposit types cannot be discussed due to the lack of thorium and uranium occurrences in the WSA and GRA.

5. Mineral Economics

Uranium and thorium are probably of little economic value in the WSA and GRA because of the lack of known occurrences of these elements.

Uranium in its enriched form is used primarily as fuel for nuclear reactors, with lesser amounts being used in the manufacture of atomic weapons and materials which are used for medical radiation treatments. Annual western world production of uranium concentrates totaled approximately 57,000 tons in 1981, and the United States was responsible for about 30 percent of this total, making the United States the largest single producer of uranium (American Bureau of Metal Statistics, 1982). The United States ranks second behind Australia in uranium resources based on a production cost of $25/pound or less. United States uranium demand is growing at a much slower rate than was forecast in the late 1970s, because the number of new reactors scheduled for construction has declined sharply since the accident at the Three Mile Island Nuclear Plant in March, 1979. Current and future supplies were seen to exceed future demand by a significant margin and spot prices of uranium fell from $40/pound to $25/pound from January, 1980 to January, 1981 (Mining Journal, July 24, 1981). At present the outlook for the United States uranium industry is bleak. Low prices and overproduction in the industry have resulted in the closures of numerous uranium mines and mills and reduced production at properties which have remained in operation. The price of uranium at the end of 1982 was $19.75/pound of concentrate.

Oil and Gas Resources

1. Known Oil and Gas Deposits

There are no known oil and gas deposits in the GRA.

2. Known Prospects, Oil and Gas Occurrences and Petroliferous Areas

No exploratory wells or oil seeps are known to be present in the GRA or the valleys surrounding the Worthington Mountains.

3. Oil and Gas Leases

There are at least 30 square miles of Federal leases over the Sand Spring and Garden Valley portions of the WSA, and there are two additional square miles in the Worthington Mountains proper.

4. Oil and Gas Deposit Types

Oil deposits that have been found and developed, and those that are being explored for in the Basin and Range to date, have been limited to the Upper Paleozoic section of the miogeosyncline and the Tertiary section of the intermontane basins. The source rocks are assumed to be in Paleozoic horizons, such as the Mississippian Chainman Shale, and perhaps also the Tertiary section.

The reservoirs at the Trap Spring and Eagle Springs oil fields in Railroad Valley are the Oligocene Garrett Ranch volcanics or equivalent, which produce from fracture porosity; or the Eocene Sheep Pass Formation, a freshwater limestone. Minor production has been recorded from the Ely(?) Formation of Pennsylvanian age at Eagle Springs. It may be that production also comes from other units in the Tertiary or Paleozoic sections in the Blackburn oil field in Pine Valley or the Currant and Bacon Flat oil fields in Railraod Valley.

5. Oil and Gas Economics

The low level of production from Nevada Basin and Range oil fields, which are remote from existing pipelines, existing refineries and consuming areas, necessitates the trucking of the crude oil to existing refineries in Utah, California and Nevada. Since the discovery of oil in Nevada in 1953, the level of production has fluctuated. Factors which have affected the production from individual wells are: reservoir and oil characteristics; Federal regulations; productivity; environmental constraints; willingness or ability of a refiner to take certain types of oil; and of course, the price to the producer, which is tied to regional, national and international prices.

Geothermal Resources

1. Known Geothermal Deposits

There are no known geothermal deposits in the GRA.

2. Known Prospects, Geothermal Occurrences and Geothermal Areas

No prospects, occurrences or thermal areas are reported to be in the GRA. Outside the GRA in Sand Spring Valley, Sand Spring (#1 on the Geothermal Occurrences and Land Classification Map) (86°F) is approximately a mile outside the southwest corner of the GRA boundary, and three wells

(#2) of approximately 250 feet in depth have "warm" to 83°F water (Garside and Schilling, 1979).

3. Geothermal Leases

There are no Federal geothermal leases in the GRA or vicinity.

4. Geothermal Deposit Types

Geothermal resources are hot water and/or steam which occurs in subsurface reservoirs or at the surface as springs. The temperature of a resource may be about 70°F (or just above average ambient air temperature) to well above 400°F in the Basin and Range province.

The reservoirs may be individual faults, intricate fault-fracture systems, or rock units having intergranular permeability -- or a combination of these. Deep-seated normal faults are believed to be the main conduits for the thermal waters rising from thousands of feet below in the earth's crust.

The higher temperature and larger capacity resources in the Basin and Range are generally hydrothermal convective systems. The lower temperature reservoirs may be individual faults bearing thermal water or lower pressured, permeable rock units fed by faults or fault systems. Reservoirs are present from the surface to over 10,000 feet in depth.

5. Geothermal Economics

Geothermal resources are utilized in the form of hot water or steam normally captured by means of drilling wells to a depth of a few feet to over 10,000 feet in depth. The fluid temperature, sustained flow rate and water chemistry characteristics of a geothermal reservoir determine the depth to which it will be economically feasible to drill and develop each site.

Higher temperature resources (above 350°F) are currently being used to generate electrical power in Utah and California, and in a number of foreign countries. As fuel costs rise and technology improves, the lower temperature limit for power will decrease appreciably -- especially for remote sites.

All thermal waters can be beneficially used in some way, including fish farming (68°F), warm water for year-round mining in cold climates (86°F), residential space heating (122°F), greenhouses by space heating (176°F), drying of

vegetables (212°F), extraction of salts by evaporation and crystallization (266°F), and drying of diatomaceous earth (338°F).

Unlike most mineral commodities remoteness of resource location is not a drawback. Domestic and commercial use of natural thermal springs and shallow wells in the Basin and Range province is an historical fact for over 100 years.

Development and maintenance of a resource for beneficial use may mean the expenditure of no dollars or hundreds of millions of dollars, depending on the resource characteristics, the end use and the intensity or level of use.

## D. OTHER GEOLOGICAL RESOURCES

One of the most famous caves in Nevada, Leviathan, is located in this GRA, inside the WSA near Sec. 31, T 1 S, R 57 E. It is located just below the crest on the western side of the range and has a spectacular entrance that can be seen for many miles out in the flat of Sand Spring Valley. The cave area already has been recognized as a unique geological area. Another cave, Lavender, is reportedly located within a mile south of Leviathan.

## E. STRATEGIC AND CRITICAL MINERALS AND METALS

A list of strategic and critical minerals and metals provided by the BLM was used as a guideline for the discussion of strategic and critical materials in this report.

The Stockpile Report to the Congress, October 1981-March 1982, states that the term "strategic and critical materials" refers to materials that would be needed to supply the industrial, military and essential civilian needs of the United States during a national emergency and are not found or produced in the United States in sufficient quantities to meet such need. The report does not define a distinction between strategic and critical minerals.

Lead, zinc and silver are strategic and critical minerals and have been mined to a limited extent in the Freiberg district. Tungsten has not been mined but is present in low grade form as scheelite in tactite in the district.

## IV. LAND CLASSIFICATION FOR G-E-M RESOURCES POTENTIAL

The geologic maps which cover the WSA include Tschanz and Pampeyan and Pampeyan, 1970, and Howard, 1978, both at a scale of 1:250,000 and both essentially the same for this WSA. The scale of these maps is too small to show a great deal of geological detail other than gross lithologies. Structural details, veining, or alteration, if present, are not shown. Even though the map detail is not satisfactory for adequately evaluating mineral resources the quality of the data is good and the confidence level in the information is good. The data on mineral resources comes primarily from Tschanz and Pampeyan and Pampeyan, 1970, and is not that detailed. Overall, the quantity of data concerning mineral resources is somewhat low, but the quality and level of confidence in that data is high.

Land classification areas are numbered starting with the number 1 in each category of resources. Metallic mineral land classification areas have the prefix M, e.g., M1-4D. Uranium and thorium areas have the prefix U. Nonmetallic mineral areas have the prefix N. Oil and gas areas have the prefix OG. Geothermal areas have the prefix G. Sodium and potassium areas have the prefix S. The saleable resources are classified under the nonmetallic mineral resource section. Both the Classification Scheme, numbers 1 through 4, and the Level of Confidence Scheme, letters A, B, C, and D, as supplied by the BLM are included as attachments to this report. These schemes were used as strict guidelines in developing the mineral classification areas used in this report.

Land classifications have been made here only for the areas that encompass segments of the WSA. Where data outside a WSA has been used in establishing a classification area within a WSA, then at least a part of the surrounding area may also be included for clarification. The classified areas are shown on the 1:250,000 mylars or the prints of those that accompany each copy of this report.

In connection with nonmetallic mineral classification, it sould be noted that in all instances areas mapped as alluvium are classified as having moderate favorability for sand and gravel, with moderate confidence, since alluvium is by definition sand and gravel. All areas mapped as principally limestone or dolomite have a similar classification since these rocks are usable for cement or lime production. All areas mapped as other rock, if they do not have specific reason for a different classification, are classified as having low favorability, with low confidence, for nonmetallic mineral potential, since any mineral material can at least be used in construction applications.

1. LOCATABLE RESOURCES

a. Metallic Minerals

WSA NV 040-242

M1-3C. This classification indicates moderate favorability for accumulation of metallic resources with a moderate confidence level. This area includes that part along the northern boundary of the WSA which is immediately adjacent to or considered part of the Freiburg mining district. The reasons for the 3 (moderate favorability) classification include: The Freiburg district adjoins this area; the geology is similar to the Freiberg district; and there are mining claims in this area. The C (moderate) confidence level is because the above is considered to be direct evidence to support the classification.

M2-3B. This classification indicates moderate favorability with a low confidence level. This area includes the alluvial cover in the northern part of the WSA that is immediately adjacent to the Freiberg district. The moderate favorability (3) is because the two igneous intrusives in the district appear to be spatially related to mineralization and both intrusives crop out partially on either side of the range at the bedrock-alluvium contact. It is conceivable that hidden beneath the alluvial cover in this area or faulted off beneath the alluvium, additional mineralization is present near unseen contacts of these intrusives with adjacent carbonate units. The B confidence level is because this data is indirect evidence as the nature of the bedrock beneath the alluvium is unknown.

M3-2B. This classification indicates a low favorability with a low confidence level. This area includes the remaining outcrop area of the Pogonip Group in the WSA. The Pogonip Group is the geologic unit in which the mineralization is hosted in the Freiberg district, and this is the reason for assigning this unit a 2 classification as there are no known claims or associated intrusive rocks in this area. The B (low) confidence level is because the above evidence is indirect only.

M4-1B. The 1 classification is for no known favorability. This area includes the outcrop area of the Eureka Quartzite on the west flank of the range. No ore deposits are known to be associated with this unit in Freiburg district. The low confidence level, B, is because there is indirect evidence to support this classification, i.e., no prospects, known mineralization or claims.

M5-2A. This classification is for low favorability, but with a very low confidence level. This area includes all the remaining Paleozoic rocks exposed in the WSA, the vast majority of which are carbonate units. Granitic stocks are found in the Freiberg district in the northern part of the mountain range. The possibility exists of more associated granitic stocks in this area to the south which may be hidden and undetected at depth. Many thousands of feet of carbonates are exposed in this classification area though with no reported metallic occurrences. The 2 (low) favorability is because carbonate units to the north are mineralizaed and to the south outside the area at Tempiute are mineralized. The A confidence level is because the available information indicates insufficient data to support this classification.

M6-2A. This classification area includes the volcanic rocks in the very southern portion of the WSA. There is no evidence of mineralization in these volcanics within or outside both the WSA and the GRA. The 2 (low favorability) classification is because the nature of the pre-Tertiary rocks underlying the volcanics are unknown and because other pre-Tertiary rocks in the area do have mineralization (i.e., Freiburg and Tempiute districts) there is a possibility of similar mineralization at depth in the Paleozoic rocks beneath the volcanics. The volcanic rocks are post mineralization. The A (very low) confidence level is because this 2 classification is conjecture and there is no supporting evidence.

M7-2A. This classification area includes all the remaining alluvial cover in the WSA. The nature of the bedrock beneath the alluvium is unknown. The 2 classification is for low favorability because as in the rationale given for classification area M6-2A, the Paleozoic rocks at depth here may contain mineralization. The A confidence level (very low) is because there is no evidence to support the possibility of mineralization at depth.

b. Uranium and Thorium

WSA NV 040-242

U1-2B. This classification covers a north-trending zone through the central part of the WSA and GRA and the northwestern and southeastern corners of the GRA. The majority of the area in the WSA is covered by Lower Paleozoic carbonates, and the areas in the GRA are covered by Tertiary volcanics. Immediately north of the WSA two granite plutons intrude the Paleozoic carbonates. These areas have low favorability with a low level of confidence for uranium fracture-filling or intensive contact-related deposits. Tertiary silicic volcanics in the southeastern

part of the WSA may be a source for uranium which could have been remobilized by ground water and deposited as fracture-fillings. Fracture-filling deposits near intrusive contacts, similar to the occurrence at the Tem Piute mine, may occur in the vicinity of the granitic intrusions just north of the WSA. The Paleozoic carbonates have very low favorability for uranium in most of the WSA due to the apparent lack of a nearby uranium source, such as intrusives or overlying volcanics.

The area has very low favorability for thorium at a very low confidence level, except possibly within the granite plutons which occur to the north of the WSA.

U2-2B. This classification covers the western and eastern margins of the WSA and the southwestern and northeastern parts of the GRA. These areas are covered by Quaternary gravels and alluvium and have a low favorability with a low confidence level for epigenetic sandstone-type uranium deposits. If uranium was present in volcanics in the northwestern and southeastern parts of the GRA, it may have been leached by ground water and deposited in the alluvial deposits. This type of occurrence is not likely within the WSA because the alluvial deposits occur adjacent to Paleozoic carbonates which are probably a poor uranium source.

Overall the area has very low favorability with a very low confidence level for thorium due to the apparent lack of source rocks. However, there is a remote possibility of monazite placer concentrations occurring in alluvium adjacent to the Tertiary granites north of the WSA.

c. Nonmetallic Minerals

WSA NV 040-242

N1-3C. This classification area of moderate favorability with a moderate confidence level includes all the carbonate units in the WSA, which is the majority of the outcrop area in the WSA. The units could be used for cement or possibly lime manufacture or for various other construction material applications.

N2-3C. This classification area of moderate favorability with a moderate confidence level includes all the outcrop area of the Eureka Quartzite in the WSA. This unit could possibly be utilized for silica production depending on a more thorough evaluation. The Eureka Quartzite is currently and has in the past been mined for silica elsewhere in southern Nevada.

N3-2B. This classification area of low favorability with

a low confidence level includes the volcanic rocks in the southern portion of the WSA. There are no known nonmetallic mineral resources known in this area, however, all rocks can be used for construction purposes and any mineral material can become an economic nonmetallic mineral if a use can be developed for its particular chemical or physical properties.

N4-3C. This classification area includes all the alluvium in the WSA. This material could be used for construction materials, sand and gravel.

2. LEASABLE RESOURCES

a. Oil and Gas

WSA NV 040-242

OG1-2A. WSA NV 040-242 is within the petroliferous Paleozoic miogeosyncline portion of eastern Nevada, host to all of the State's oil fields. There is also evidence that the Tertiary section may also be a source of at least some of the oil encountered in wells. Many of the exploratory wells drilled have encountered oil and/or gas shows in the Paleozoic and Cenozoic strata, largely in the more permeable carbonate (Eocene Sheep Pass Formation) and volcanic (Garrett Ranch Formation) sections. Similar or equivalent rock units may occur in the subsurface within the WSA and vicinity. Because of the structural complexity and the resulting discontinuity of the stratigraphic section, relatively closely-spaced exploratory drilling is needed to prove or disprove the potential of most of the region.

The presence of extensive leasing on Federal lands within the WSA, and a deep exploratory test closeby indicates the oil industry's recognition of oil and gas potential beneath the WSA.

b. Geothermal

WSA NV 040-242

G1-2A. The WSA is centrally located regionally within an area of low- to moderate-temperature geothermal resources which are genetically related to the deep-seated Basin and Range faulting. The low-temperature spring and wells beyond the GRA boundary are in alluvium, but are probably associated with Basin and Range faulting hidden beneath the valley sediments. This faulting is not obviously on structural trend with the WSA. However both the eastern and western sides of the WSA extend well into the surrounding valleys. North-south-trending faults are

believed to be the major Cenozoic age structural control for the Worthington Mountains. These faults and those beneath the Sand Spring Valley are all potential conduits for thermal waters rising from great depths. They may be present in the near subsurface beneath the alluvium covered portions of the WSA.

G2-1A. This classification incorporates the main mountain mass which is less likely host to the younger Cenozoic faults that act as thermal water conduits.

c. Sodium and Potassium

S1-1D. There are no sodium or potassium resources known or suspected to exist in the WSA. There is no classification map for this commodity.

3. SALEABLE RESOURCES

The saleable resources in the WSA have been discussed above under nonmetallic mineral resources and includes classification area N4-3C.

## V. RECOMMENDATIONS FOR ADDITIONAL WORK

More detailed mapping of both the Freiburg district and the rest of the Worthington Range would greatly help in determining mineral resource favorability within the WSA. Further contacting past claim holders or major mining companies that have done work in the area may also shed more light on the potential mineralization.

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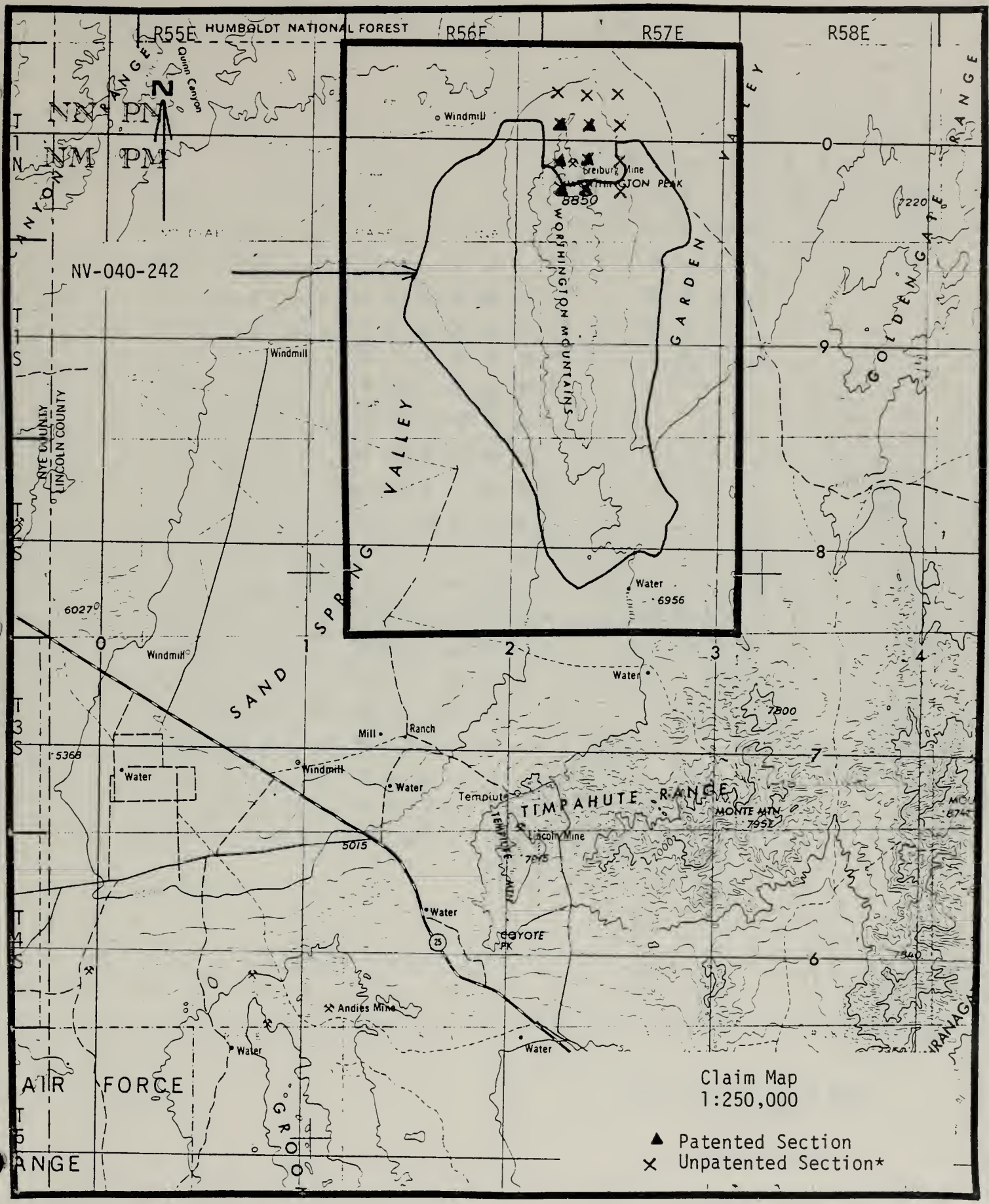
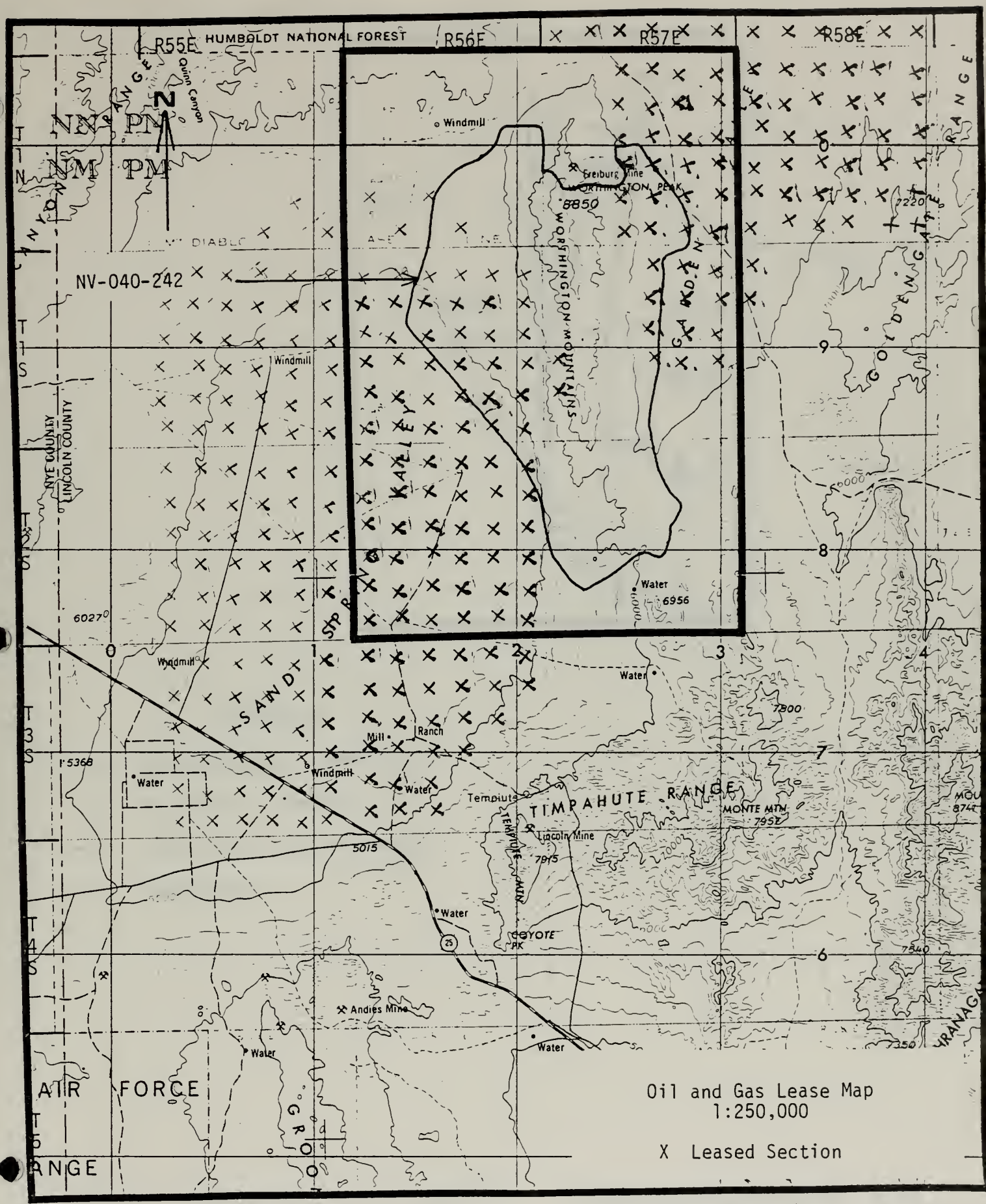



* X denotes one or more claims per section

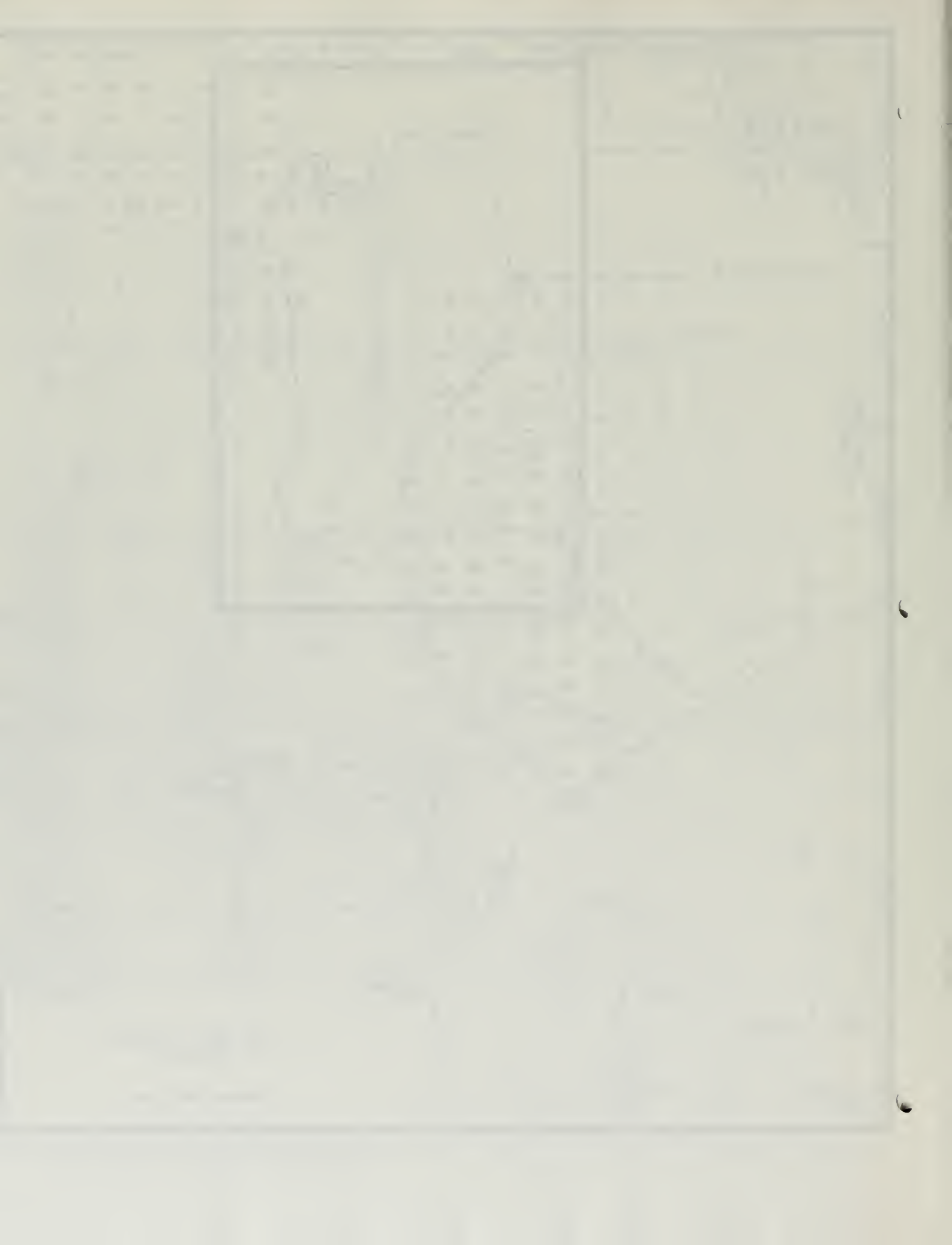
Worthington Mountains GRA NV-18

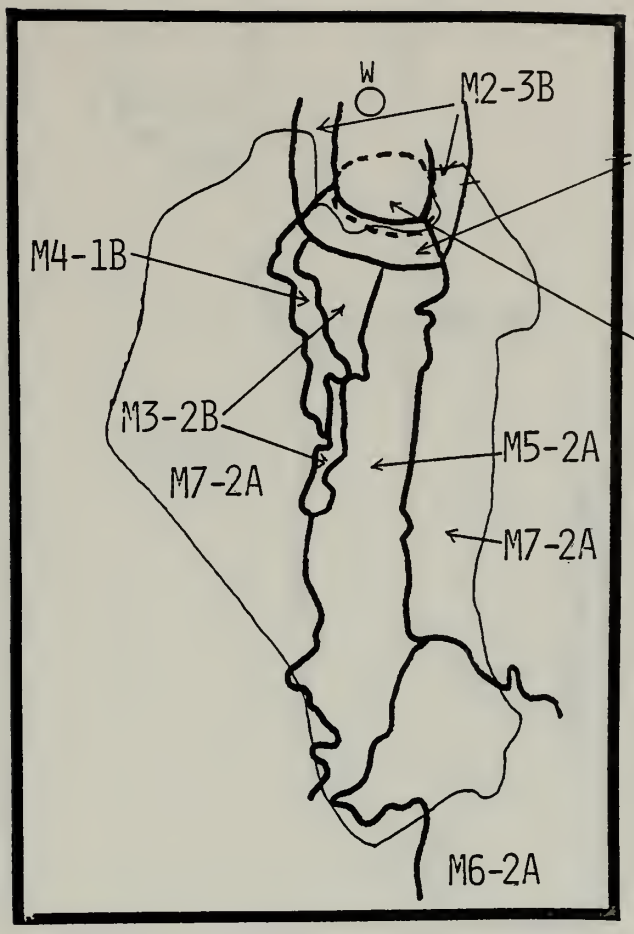



Oil and Gas Lease Map
1:250,000

X Leased Section

Worthington Mountains GRA NV-18





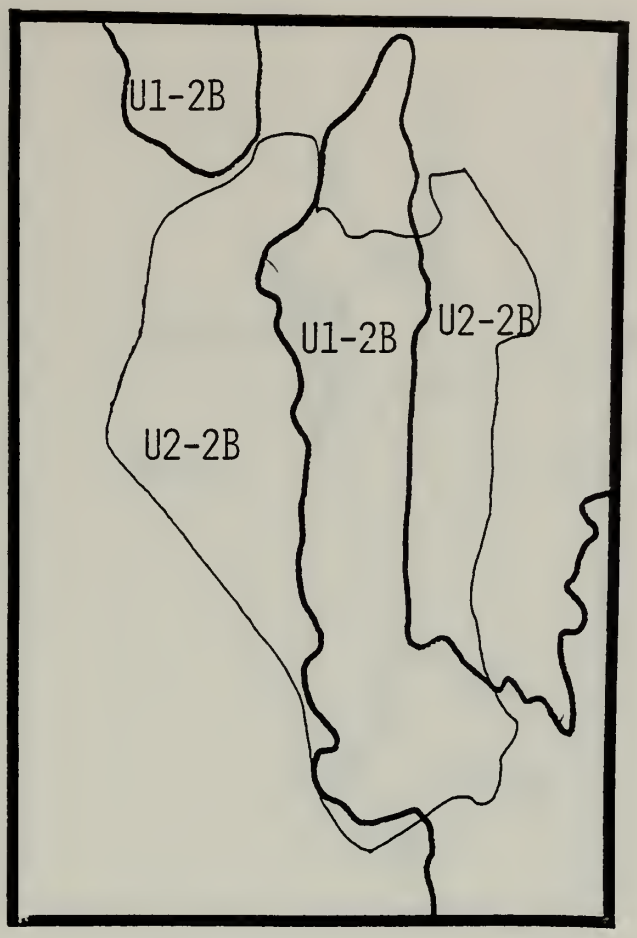

EXPLANATION

---- Mining District, commodity

○ Occurrence, commodity

— Land Classification Boundary

—— WSA Boundary

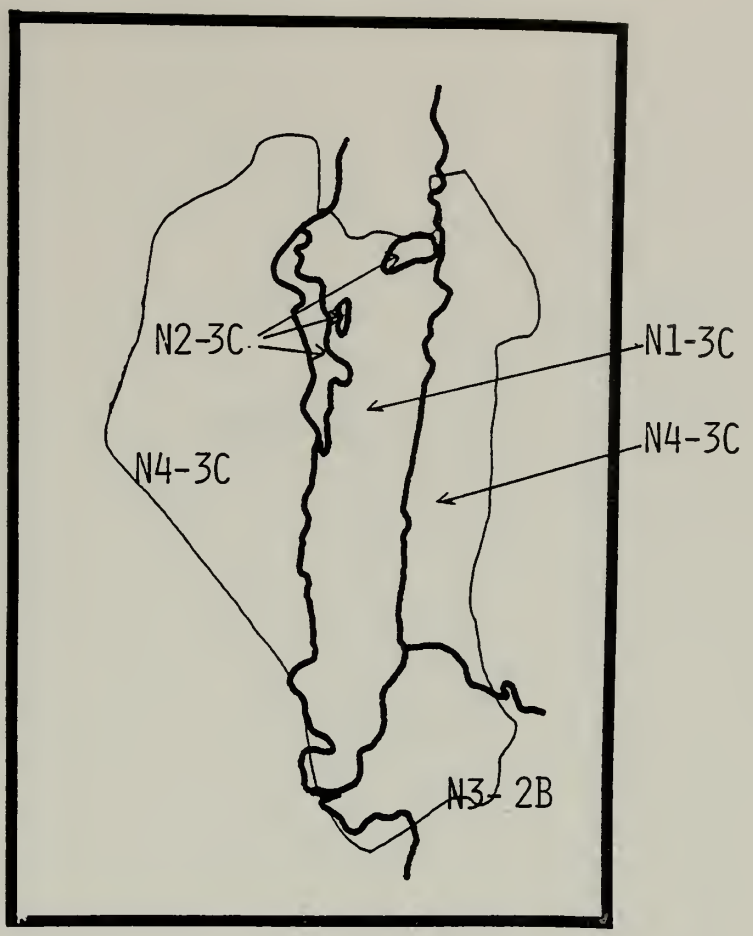



EXPLANATION

- Uranium Occurrence
- Land Classification Boundary
- WSA Boundary

Land Classification - Mineral Occurrence Map/Uranium

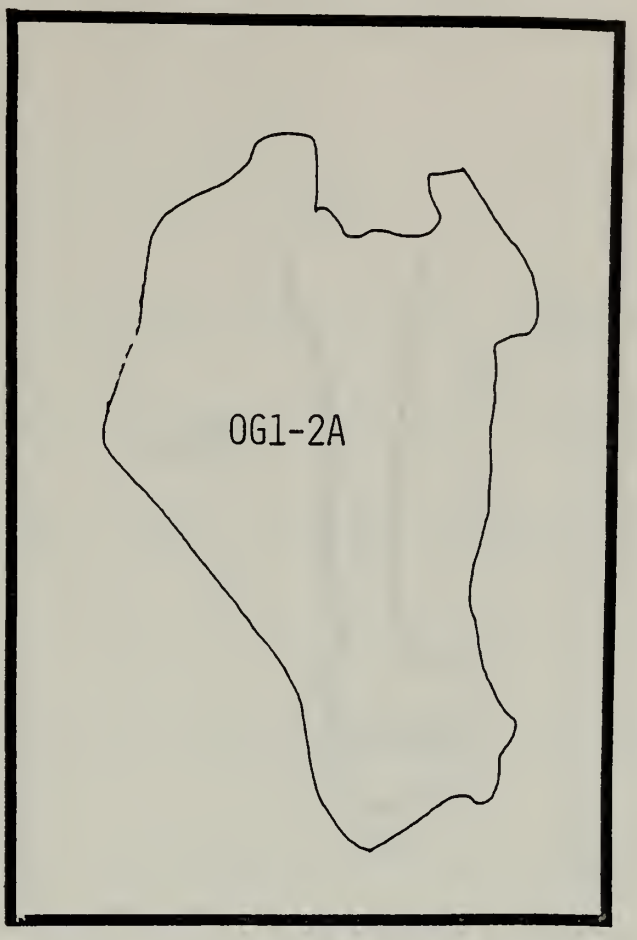
Worthington Mountains GRA NV-18
Scale 1:250,000




EXPLANATION

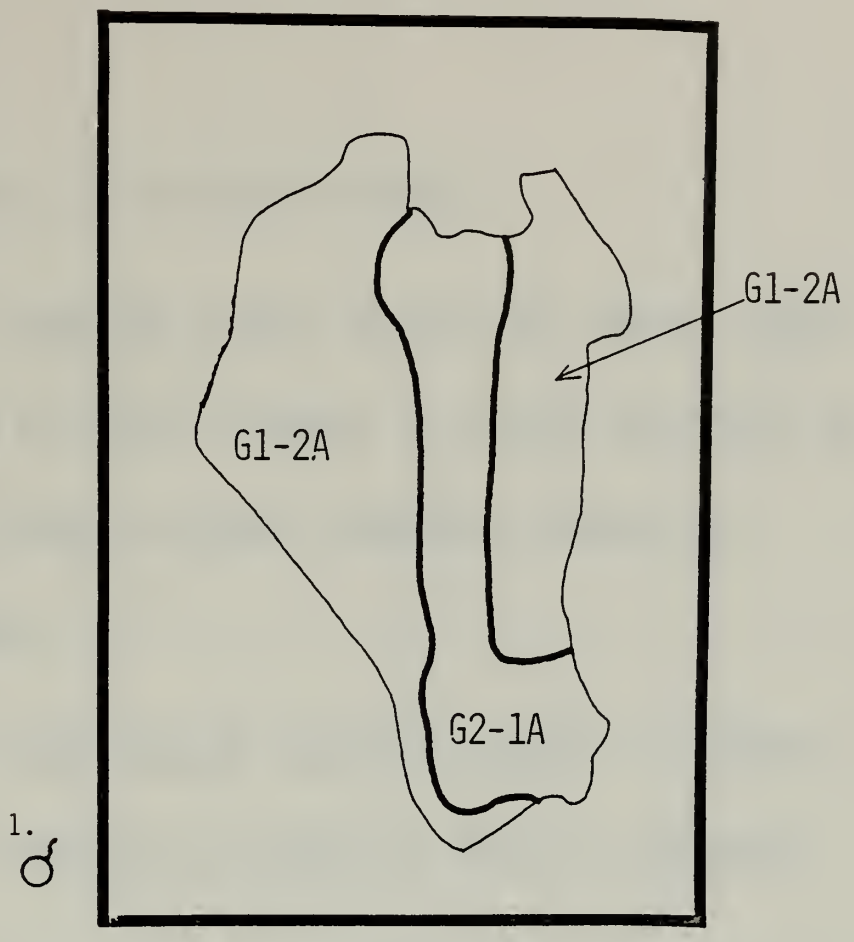
Land Classification Boundary

WSA Boundary




EXPLANATION

—— WSA and Land Classification Boundary




EXPLANATION

1. Reference location (see text)

Thermal Well

Thermal Spring

Land Classification Boundary

WSA Boundary

2.

Worthington Mountains GRA NV-18

Land Classification - Mineral Occurrence Map/Geothermal Scale 1:250,000

## LEVEL OF CONFIDENCE SCHEME

A. THE AVAILABLE DATA ARE EITHER INSUFFICIENT AND/OR CANNOT BE CONSIDERED AS DIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES WITHIN THE RESPECTIVE AREA.

B. THE AVAILABLE DATA PROVIDE INDIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

C. THE AVAILABLE DATA PROVIDE DIRECT EVIDENCE, BUT ARE QUANTITATIVELY MINIMAL TO SUPPORT TO REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

D. THE AVAILABLE DATA PROVIDE ABUNDANT DIRECT AND INDIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

# CLASSIFICATION SCHEME

1. THE GEOLOGIC ENVIRONMENT AND THE INFERRED GEOLOGIC PROCESSES DO NOT INDICATE FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

2. THE GEOLOGIC ENVIRONMENT AND THE INFERRED GEOLOGIC PROCESSES INDICATE LOW FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

3. THE GEOLOGIC ENVIRONMENT, THE INFERRED GEOLOGIC PROCESSES, AND THE REPORTED MINERAL OCCURRENCES INDICATE MODERATE FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

4. THE GEOLOGIC ENVIRONMENT, THE INFERRED GEOLOGIC PROCESSES, THE REPORTED MINERAL OCCURRENCES, AND THE KNOWN MINES OR DEPOSITS INDICATE HIGH FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

## MAJOR STRATIGRAPHIC AND TIME DIVISIONS IN USE BY THE U.S. GEOLOGICAL SURVEY

| Erathem or Era | System or Period | Series or Epoch | Estimated ages of time boundaries in millions of years |
|---|---|---|---|
| Cenozoic | Quaternary | Holocene | |
| | | Pleistocene | 2-3 [1] |
| | Tertiary | Pliocene | 12 [1] |
| | | Miocene | 26 [2] |
| | | Oligocene | 37-38 |
| | | Eocene | 53-54 |
| | | Paleocene | 65 |
| Mesozoic | Cretaceous [4] | Upper (Late)<br>Lower (Early) | 136 |
| | Jurassic | Upper (Late)<br>Middle (Middle)<br>Lower (Early) | 190-195 |
| | Triassic | Upper (Late)<br>Middle (Middle)<br>Lower (Early) | 225 |
| Paleozoic | Permian [4] | Upper (Late)<br>Lower (Early) | 280 |
| | Carboniferous Systems: Pennsylvanian [4] | Upper (Late)<br>Middle (Middle)<br>Lower (Early) | |
| | Carboniferous Systems: Mississippian [4] | Upper (Late)<br>Lower (Early) | 345 |
| | Devonian | Upper (Late)<br>Middle (Middle)<br>Lower (Early) | 395 |
| | Silurian [4] | Upper (Late)<br>Middle (Middle)<br>Lower (Early) | 430-440 |
| | Ordovician [4] | Upper (Late)<br>Middle (Middle)<br>Lower (Early) | 500 |
| | Cambrian [4] | Upper (Late)<br>Middle (Middle)<br>Lower (Early) | 570 |
| Precambrian [3] | | Informal subdivisions such as upper, middle, and lower, or upper and lower, or younger and older may be used locally. | 3,600+ [3] |

[1] Holmes, Arthur, 1965, Principles of physical geology: 2d ed., New York, Ronald Press, p. 360-361, for the Pleistocene and Pliocene; and Obradovich, J. D., 1965, Age of marine Pleistocene of California: Am. Assoc. Petroleum Geologists, v. 49, no. 7, p. 1057, for the Pleistocene of southern California.

[2] Geological Society of London, 1964, The Phanerozoic time-scale; a symposium: Geol. Soc. London, Quart. Jour., v. 120, supp., p. 260-262, for the Miocene through the Cambrian.

[3] Stern, T. W., written commun., 1968, for the Precambrian.

[4] Includes provincial series accepted for use in U.S. Geological Survey reports.

Terms designating time are in parentheses. Informal time terms early, middle, and late may be used for the eras, and for periods where there is no formal subdivision into Early, Middle, and Late, and for epochs. Informal rock terms lower, middle, and upper may be used where there is no formal subdivision of a system or of a series.

GEOLOGIC NAMES COMMITTEE, 1970